Effect of Prophylactics Knee Bracing on Balance and Joint Position Sense

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ABSTRACT:
Prophylactic knee braces are designed to prevent and reduce the severity of ligamentous injuries to the knee. Conflicting evidence is reported concerning their efficacy. The purpose of this study was to determine the effect of prophylactic knee bracing on the proprioceptive parameters of balance and joint position sense. Active and passive joint position sense were assessed using the Cybex II + Isokinetic Dynamometer (Cybex Division of Lumex, Inc, Ronkonkoma, NY). Sway index and center of balance were assessed using the Chattecx Dynamic Balance System (Chattanooga Group, Hixson, TN). Thirty-six male subjects were measured with and without prophylactic knee braces. Joint position sense was measured in degrees of error from four preselected target angles. Sway index and center of balance measures were recorded in centimeters under the following platform conditions: stable, plantar flexion/ dorsiflexion, and inversion/eversion. Separate repeated measures ANOVAs were performed to determine if there were differences between the braced and unbraced conditions for center of balance, sway index, and joint position sense. Center of balance with the platform moving in a dorsi/plantar flexion direction was improved while wearing the knee braces. In addition, differences in both center of balance and sway were recorded across the three platform conditions with and without knee bracing. Bracing did not affect joint position sense. The results of this study suggest that prophylactic knee braces have very little impact on proprioceptive feedback mechanisms.

Article:
Knee injuries continue to plague the athletic population, especially in the sport of football. Advances in the treatment and rehabilitation of sport-related knee injuries have hastened recovery time and subsequent return to sport. However, prevention of knee injuries remains elusive despite attempts to limit the frequency of these disabling conditions. Prophylactic knee braces are designed to prevent and help reduce the frequency and severity of knee injuries and are used primarily in football. Despite the inconsistencies regarding their purported effectiveness, many clinicians still advocate their use.

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Researchers have conducted several epidemiology studies to determine the effectiveness of prophylactic knee bracing on knee injury prevention. Some reported reduction of knee injuries[20,27]; others reported an increase in knee injuries[20,27]; and still others reported no effect.[9] A number of studies have been focused on the effect of prophylactic knee bracing on performance.[6,10,15,24,26,29] The primary emphasis of these studies has been on the muscle performance parameters of speed, strength, endurance, and agility. Proprioception is a parameter that has recently received considerable attention in sports medicine literature. Several recent reports have assessed the proprioceptive benefits of neoprene sleeves and elastic bandages.[4,22,25] The importance of this neuromuscular mechanism in injury and reinjury pathology is not clearly understood. We found no studies examining the effect of prophylactic knee braces on proprioception.

Proprioception is the ability to acknowledge input from various mechanoreceptors in muscles, tendons, and joints. Information from mechanoreceptors is then conducted along large-diameter myelinated nerve fibers that have high conduction velocities. It is processed by the central nervous system.[2] The majority of sensory inputs from the joint mechanoreceptors are processed through the dorsal root spinal ganglion, ascend through the posterior spinal cord, and are conducted to the cerebral cortex.[14] The central nervous system ultimately communicates by indicating where the limb is in space. Proprioception can be assessed by measuring kinesthesia (perception of movement) and joint position sensibility (perception of joint position). Traditionally, this has been done in an open kinetic chain using the methods of threshold to detection of passive motion or joint position sense. The knee has served as the primary test limb for most studies.[3.17,22,25] Closed kinetic chain assessment of proprioception can be performed by examining balance control. Somatosensory information from the feet in contact with the support surface is the preferred sensory input for the control of balance in the healthy athlete.[30] Center of balance data can be considered a proprioceptive measurement as assessed in the closed kinetic chain.[19] Normal center of balance can be defined as the point between the feet where the ball and heel of each foot has 25% of the body weight. The purpose of this study was to determine the effect of prophylactic knee bracing on the proprioceptive parameters of balance and joint position sense.

METHODS

Thirty-six healthy male subjects (age = 21.7 ± 5.5 yr, ht = 69.9 ± 2.6 in, wt = 166 ± 19.8 lb) volunteered to participate in this study. Subjects were injury-free and had no previous exposure to prophylactic knee bracing. Each read and signed a consent form approved by a University Committee for the Protection of Human Subjects. Subjects reported for testing barefooted and wearing running shorts. We tested subjects under both the braced and unbraced conditions on the same occasion. The order of testing was randomly assigned according to either joint position sense testing or balance testing. We used a counterbalance scheme to delineate the order of each evaluation within each of the two test sequences. The scheme used for balance testing included consideration for bracing, stance, and platform movement. The joint position sense counterbalance protocol considered the factors of bracing, type of repositioning, and target angle.

Bracing

The McDavid Knee Guard (M-202; McDavid Knee Guard Inc, Chicago, IL) was chosen for use in this study. This is a popular, commercially available prophylactic knee brace used by many intercollegiate and interscholastic football programs. The knee brace features a geared polycentric hinge with a reversible hyperextension stop that allows for bilateral fitting. The brace is held in place by neoprene wrap-on cuffs with an extra VELCRO® strap over the calf cuff to prevent slippage. Each brace was fitted and applied according to the manufacturer's guidelines. The brace was worn unilaterally on the dominant leg for single-leg balance assessments and joint position sense evaluations. The brace was worn bilaterally for the braced double-leg balance assessments. Dominance was determined by asking subjects to identify the leg they would use to kick a ball.

Assessment of Joint Position Sense

The Cybex II + Isokinetic Dynamometer (Cybex Division of Lumex, Inc, Ronkonkoma, NY) was used to assess joint position sense. The reproduction of passive positioning is defined as the ability to reproduce a position in which the joint has been previously placed.[3,13] The Cybex II + has a built-in electrogoniometer that can be conveniently used to assess this parameter of proprioception. The Cybex II + computer monitor allowed for a constant monitoring of joint range of motion in degrees. We positioned the subjects supine on the Cybex II + test table (Fig 1). In this position the hip was at approximately 0° of extension, and the knee joint was flexed at approximately 90°. A stabilizing strap was placed across the subject's chest. The shin pad strap was reversed and positioned behind the calf at a level just above the malleoli. This position helped to minimize any extraneous cutaneous feedback from the lower limb. We blindfolded the subjects to eliminate any visual cues. The velocity of the dynamometer arm remained constant at 12.5°/s. This coincides with the weigh-limb button on the Cybex II + remote digital speed control.

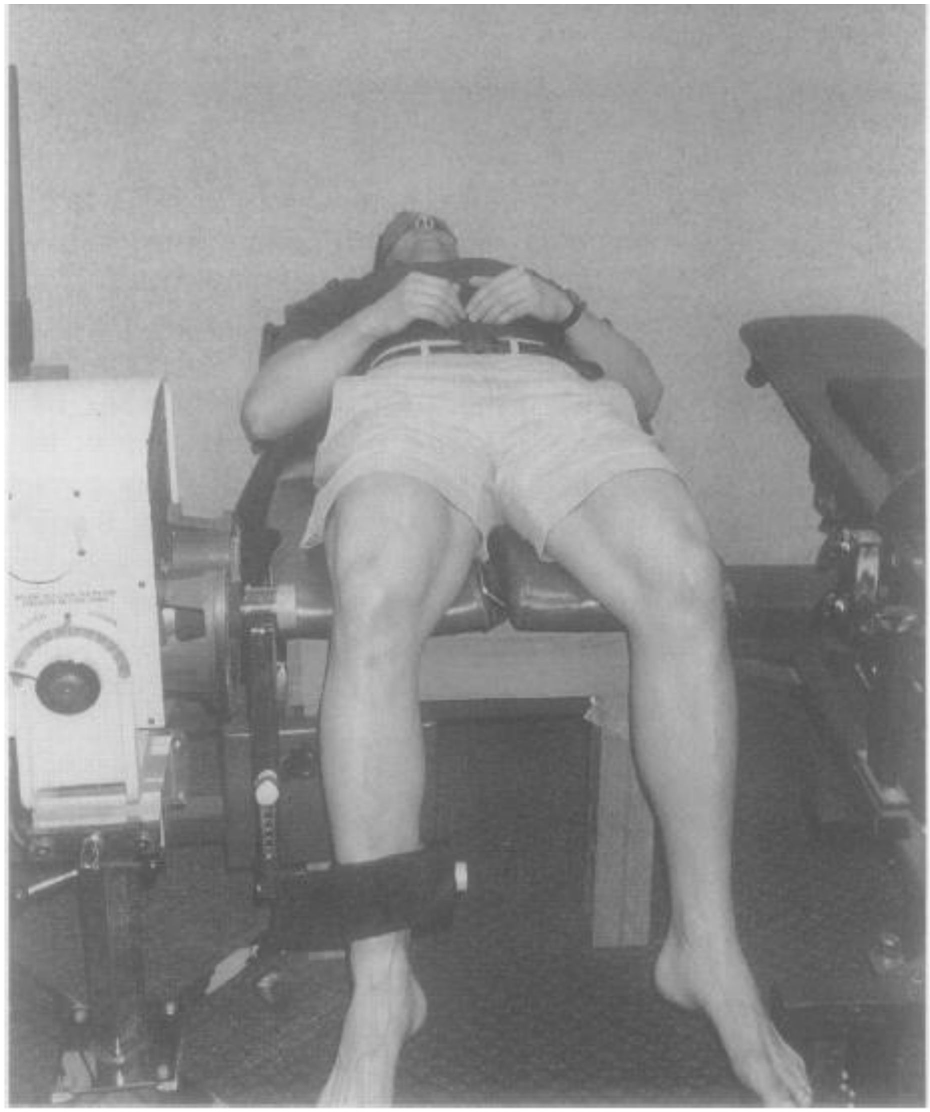

Fig 1. Subject positioning on the Cybex II + Isokinetic Dynamometer for joint position testing.

Using a 4 X 4 balanced Latin square, we randomized the order of target angle presentation. This enabled us to insure that, first, every target angle occurred in each of the four presentations and, second, that each angle preceded every condition as many times as it followed that condition. Starting from a position of approximately 90° of knee flexion, we zeroed the Cybex II + goniometer. This was considered the starting point for each of the evaluations. We then passively extended the subject's leg forward to one of four preselected target angles. The selected target angles were 15°, 25°, 35°, and 75°. These angles were selected to stimulate different joint mechanoreceptors at both the extreme and midpoint of the range of motion. Once the target angle was reached, the limb was maintained at that position for 5 seconds. The subject then returned his limb to the starting position (zero point on the Cybex II + goniometer reading). After a brief pause, we asked the subjects to actively reposition their limb to the previously placed angle. Subjects verbally indicated to the examiner when they felt that they had achieved the repositioned angle, and the joint angle data were extracted from the Cybex II + computer. We determined the error score by taking the difference between the actual and repositioned joint angles. Absolute values of the four joint angle error scores were then summed together. We used the average of these four scores as the error score for each subject.

We also examined passive repositioning, in an attempt to examine differences between active and passive judgments on joint position sense. In this procedure, we passively repositioned the limb in place of active repositioning by the subject. The procedure was identical with active reposition testing in all other respects.

Assessment of Balance

Each subject was assessed for closed kinetic chain balance using the Chattecx Dynamic Balance System (Chattanooga Group, Hixson, TN). The moderate to strong reliability of this machine has been previously reported.[7,21,23] All balance tests were performed with the eyes open and the subjects barefooted. The subjects were tested under single-leg and double- leg stance conditions. In addition, subjects were tested using three different platform movements: stable (no movement), dynamic plantar flexion/dorsiflexion, and dynamic inversion/ eversion. The exact sequence for stance, platform, and brace conditions was randomized and counterbalanced according to a Latin square. This was done in an attempt to eliminate both learning and order effects.

Each balance evaluation included a 20-second practice trial followed immediately by a 20-second test trial. We chose this time sequence to equate to the common subjective Romberg balance test. A brief rest period was allowed during the foot (force) plate change period. All manufacturer's safety guidelines were followed during each test. For the single-leg assessments, subjects stood on their dominant legs with their arms at their side and their opposite knees bent at a 45° angle (Fig 2). They looked straight ahead at an "X" marked on the wall. If a touch down occurred at any time during the test trial, the entire trial effort was repeated. The same procedure was used for both the braced and unbraced conditions.

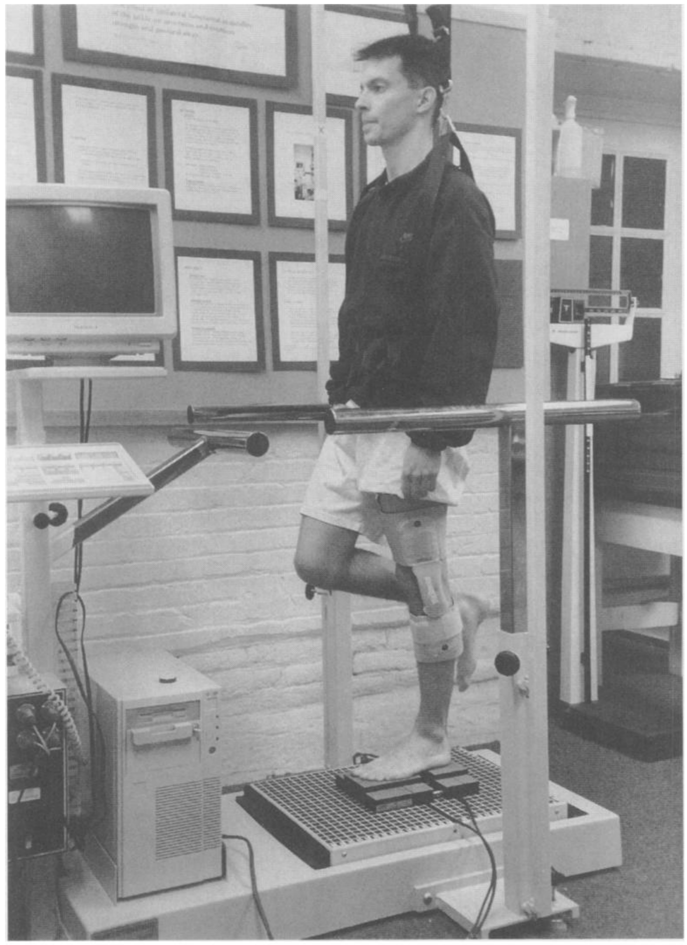

Fig 2. Subject positioning on the Chattecx Dynamic Balance System for the single-leg (dominant) stance test.

Sway index values were calculated for each stance, platform, and brace condition. Sway index is a numerical value in centimeters of the standard deviation of the time and distance the subject spends away from his/her center of balance. This is sometimes referred to as the dispersion index. Center of balance measures were calculated by using the Pythagorean Theorem (distance formula) for the hypotenuse of a triangle. The *x* and *y* coordinates generated from the device were used in the formula (squared root of $x^2 + y^2$) to determine the corresponding hypotenuse distance. This represents the distance subjects maintained their center of gravity away from their base of support.

Statistical Analysis

We used the SPSS Release 4.1 Statistical Package to analyze the data. Sway index, center of balance, and joint position sense error scores served as the dependent measures. A two-factor repeated measures ANOVA was used to determine if any differences existed between the braced and unbraced conditions for all three dependent measures. For the measures of sway index and center of balance, the within-subject factors included bracing (braced vs unbraced) and platform movement (stable, plantar flexion/dorsiflexion, and inversion/eversion). Separate analyses were performed for both the single-leg (dominant) and double-leg stances. For the measure of joint position sense error scores, the within-subject factors included bracing (braced vs unbraced) and motion (active vs passive).

RESULTS

Knee bracing improved center of balance under one dynamic condition during the double-leg stance [F(2,70) = 3.88, *p* = .03; Fig 3]. Tukey post hoc tests revealed that there was a significant difference between the mean values for the dorsi/ plantar flexion motion during the braced and unbraced conditions (Table 1). In addition, center of balance was worse in the unbraced group during double-legged stance dorsi/plantar flexion movement than during inversion/eversion movement. Knee bracing had no effect on the other double-leg dynamic or static conditions.

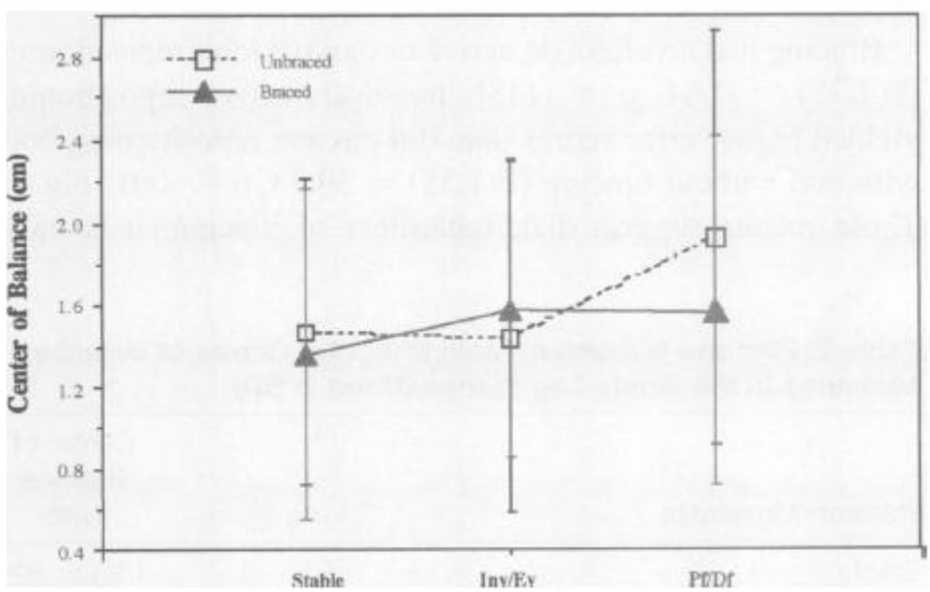

Fig 3. Graph of significant interaction for the center of balance scores in the double-leg stance during stable, inversion/eversion, and plantar flexion/dorsiflexion platform conditions.

There was no difference in center of balance between the braced and unbraced groups during the single-leg stance while on a stable or dynamic platform [F(2,70) = .76, *p* = .5; Table 1]. There were differences in center of balance, however, between the three platform conditions when both the braced and unbraced groups were combined [F(2,70) = 3.19, *p* = .05; Table 2]. Tukey post hoc tests indicated that the center of balance scores during the stable platform condition were significantly higher than those during the inversion/eversion platform movement.

Table 1. Center of Balance (cm) and Sway Index (cm) Between Braced and Unbraced Conditions (Mean ± SD)

Platform Condition	Unbraced (cm)	Braced (cm)
Double-leg center of balance		
Stable	1.47 ± .74	1.36 ± .81
Inversion/eversion	1.44 ± .86	1.59 ± .73
Dorsi/plantar flexion	1.93 ± 1.00	1.57 ± .85
Single-leg center of balance		
Stable	1.30 ± .73	1.26 ± .67
Inversion/eversion	.96 ± .66	1.14 ± .86
Dorsi/plantar flexion	1.05 ± .71	1.17 ± .74
Double-leg sway index		
Stable	.32 ± .16	.34 ± .18
Inversion/eversion	1.19 ± .49	1.14 ± .37
Dorsi/plantar flexion	1.10 ± .38	1.09 ± .48
Single-leg sway index		
Stable	.69 ± .21	.70 ± .23
Inversion/eversion	.87 ± .18	.83 ± .20
Dorsi/plantar flexion	1.14 ± .28	1.14 ± .31

Subjects swayed more while the platform was moving in either the dorsi/plantar flexion direction or inversion/eversion during both the single-leg [$F(2,70) = 72.38$, $p < .001$; Table 3], and double-leg stances [$F(2,70) = 121.48$, $p < .001$; Table 3]. There were no differences in sway index, however, between the braced and unbraced groups during either stance condition (Table 1).

Bracing had no effect on active or passive joint repositioning [$F(1,35) = 2.64$, $p = .113$]; however, active repositioning yielded higher error scores than did passive repositioning both with and without bracing [$F(1,35) = 30.53$, $p < .001$; Fig 4]. These results suggest that, regardless of bracing, it is more difficult for subjects to reposition their lower limb actively than when someone assists with that repositioning.

Table 2. Platform Movement Main Effect for Center of Balance Measures in the Single-Leg Stance (Mean ± SD)

Platform Movement	Center of Balance (cm)
Stable	1.28 ± .69
Inversion/eversion	1.05 ± .77[a]
Dorsiflexion/plantar flexion	1.11 ± .72

[a] Significantly different from stable platform condition.

Table 3. Sway Index During Single-Leg and Double-Leg Stance for Three Platform Movement Conditions (Mean ± SD)

Platform Movement	Sway Index (cm)
Single-leg stance	
Stable	.69 ± .22
Inversion/eversion	.85 ± .19[ab]
Dorsiflexion/plantar flexion	1.14 ± .29[a]
Double-leg stance	
Stable	.33 ± .17
Inversion/eversion	1.17 ± .43[a]
Dorsiflexion/plantar flexion	1.10 ± .43[a]

[a] Significantly different from stable platform condition.
[b] Significantly different from dorsi/plantar flexion platform condition.

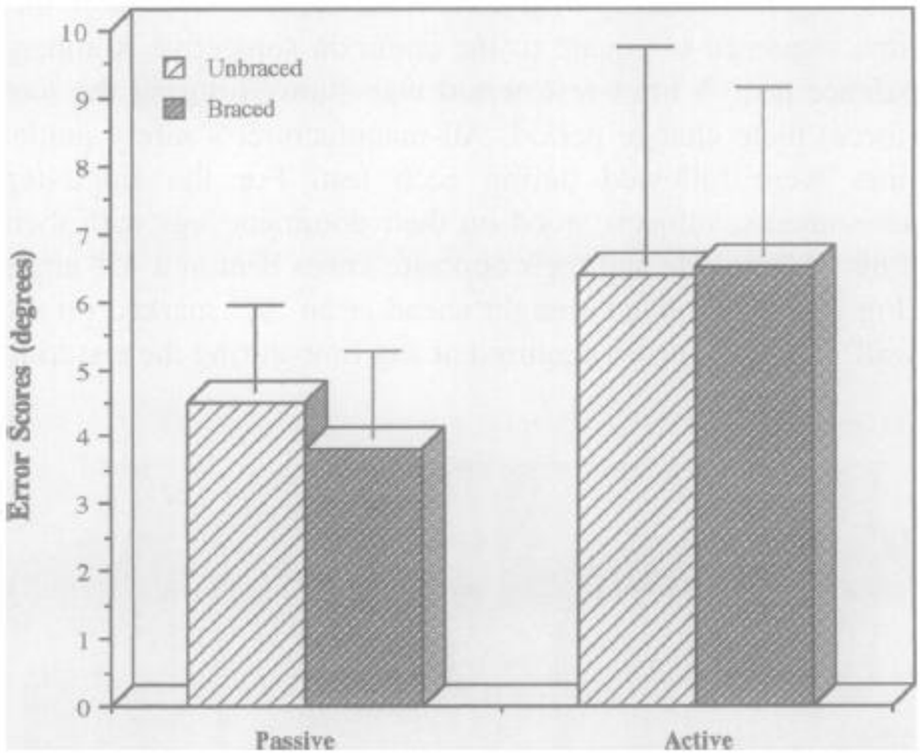

Fig 4. Joint position error scores during passive and active modes of repositioning.

DISCUSSION

Harrison et al[16] reported no differences in postural sway of the dominant and nondominant legs or between the ACL reconstructed legs and the opposite unaffected leg during single-leg standing. They concluded that the single-leg standing balance test may only be appropriate for conditions in which balance is greatly affected.[16] As expected, our subjects swayed more when the balance platform was undergoing movement, either in the dorsi/plantar flexion direction or inversion/eversion. This is consistent with the findings of Hertel,[19] who theorized that the platform movement forces a change in the muscles that are used to maintain balance. This change in muscle activation then leads to an increase in postural sway.

We had hypothesized that the braced condition would enhance the ability to reproduce both active and passive joint position sense. However, there was no interaction between the bracing and motion conditions, which is inconsistent with others who have reported enhancement in kinesthesia via the use of bracing and wrapping. Lephart et al[22] reported that kinesthesia (threshold to detection of passive motion) was improved in post—anterior cruciate ligament reconstructed subjects while wearing neoprene sleeves. They suggested that the sleeves augmented afferent input by providing increased cutaneous stimulation.[22] An elastic bandage around the pathological knee improved the performance of patients when applied to a joint with poor joint position sense (ie, osteoarthritic or soon after joint replacement), but not when applied to their uninjured knee.[4] In a more recent study, Perlau et al[25] reported that knee joint proprioception was improved while wearing an elastic bandage in a group of uninjured subjects. Wrapping and bandaging apparently stimulates the skin during joint motion and increases the pressure on the underlying musculature and joint capsule.[25] Afferent feedback from a number of receptors located in the skin, muscles, ligaments, and joint capsule contribute to the overall proprioceptive mechanism at the knee joint[2,8] Most of the cutaneous receptors respond to changes in movement and are rapidly adaptive.[14] It is theorized that wraps will provide the most potential for increased proprioceptive feedback during joint motion, and less of a benefit during stable positions.

We believe the differences in our findings may be because the neoprene wraps holding the prophylactic knee braces in place do not completely encircle the knee joint, thus interrupting enhancement in cutaneous stimulation. Most commercially available prophylactic knee braces are held in place by either neoprene or elasticized wraps that are secured to the thigh and calf region of the leg. It seems apparent from our findings that this configuration does not enhance joint position sense. The impact of securing the braces in place by a wrapping or bandage that completely covers the knee joint on kinesthesia is unknown. Further study on the effects of securing knee braces in place by taping or complete neoprene sleeves is warranted. Furthermore, we may attribute the different results in our study to the fact that we used healthy subjects with no history of knee problems. Barrett et al [4] suggested that wearing a bandage improves joint position sense in knees in which proprioception is impaired. Our subjects did not have a history of such joint position deficits.

Our findings suggest that passive knee joint position sense is significantly better (less error) than active knee joint position sense. This is consistent with Gross,[13] who demonstrated that passive judgments were significantly better than active judgments of ankle joint position in control subjects without ankle sprains. Gross" hypothesized that muscle receptors are involved more significantly in the perception of joint movement than in the perception of joint position. Muscle receptors are viewed as mechanoreceptors with frequencies of discharge that increase in response to stretch.[11,12] This helps to explain why the error scores for active joint positioning were higher (significantly greater) than the error scores for passive joint positioning in our study. The processing and interpretation of additional input from muscle afferent and efferent structures may have resulted in the increase in error for the active movements, while the reduction of this processing may have enhanced the passive motions.[13] Bernier[5] recently conducted a study examining the effects of training on joint position sense in subjects with functionally unstable ankles. Our study is consistent with her findings in that all three of her study groups had significantly higher error scores with active repositioning versus passive repositioning. Our results are also consistent with the work of Rymer and D'Almeida,[28] who examined the effects of muscle contraction on joint position sense. They stated that if muscle receptor afferents contribute to joint position sense, then the competing effects of externally versus internally (fusimotor) imposed changes provide a potential source of conflicting information.[28] This, in turn, can lead to errors in perceived limb position.

Previous research has studied the effects of prophylactic knee bracing on functional and muscular performance.[6,10,18,24,26,29] The true effect of these protective devices on performance is still debatable. If one considers closed chain assessment of balance a marker of functional performance, then our results are consistent with those showing no deficits in performance due to prophylactic knee bracing. Hansen[15] showed no deficits in isokinetic muscle performance while wearing prophylactic knee braces. Several early studies using the Arco Brace (the precursor to the McDavid Knee Guard) indicated that this prophylactic knee brace had no effect on running speed and agility (A Johnson, unpublished data, 1969 and TL May, unpublished data, 1981).[18] A similar study by Clover (unpublished data, 1983) showed no decline in running speed while wearing the Anderson Knee Stabler. Our findings conflict with others who have reported significant deficits due to brace wearing. Prentice et al[26] reported that forward running speed was decreased while wearing prophylactic knee braces. This study was conducted on male subjects unaccustomed to knee brace use. Fujiwara et al[10] studied the effect of bracing with regard to previous exposure to brace wear. They found that 40-yard dash times were faster while not wearing the brace. They also found significant differences between experienced and nonexperienced users for 40-yard dash times, backward running times, and square cone agility drills.[10] They suggested that familiarization with bracing may be an important consideration for those wishing to wear prophylactic knee braces. Recently, Borsa et al[6] reported on the effect of prophylactic knee braces on isokinetic strength, anaerobic power, and forward sprint speed. Their results revealed deficits in strength, anaerobic power during knee extension, and slower sprint times while wearing the prophylactic knee braces.[6] All the subjects in this study were unaccustomed to wearing prophylactic knee brace.

Prophylactic knee braces appear to improve center of balance measures in a double-leg stance during the dorsi/plantar flexion platform movement. The results of this study also suggest that prophylactic knee bracing neither enhances nor inhibits passive and active joint position sense in healthy male subjects unaccustomed to brace use. Decisions to brace athletes should be made based on factors other than those having the potential to impact on proprioceptive feedback mechanisms. Future research should focus on the effect of prophylactic knee bracing on other proprioceptive and kinesthetic measures.

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